CLASS-3

Device Fabrication Lab

Metallization of Oxidized Silicon Wafer

Outline

- Objective
- Basic idea of Metallization
- Different methods of Metallization
- Metallization by Thermal Evaporation
- Necessity of high vacuum for Thermal Evaporation
- Metal used for Metallization
- Equipment used for Metallization
- **Experimental Procedure** for Metallization of Oxidized Silicon wafer
- Observation & Conclusion

Metallization of Silicon wafer

Objective:

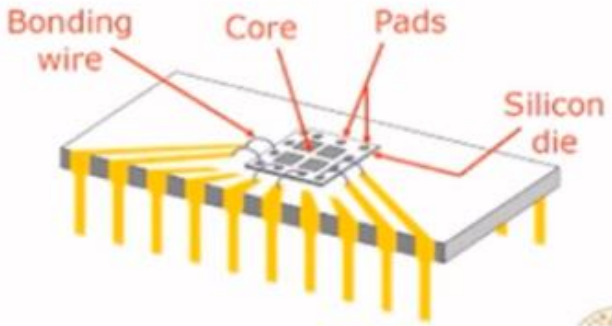
- To deposit aluminium film on a oxidized silicon substrate by thermal evaporation
- To measure the thickness of the deposited metal film

Basic idea of Metallization:

- Metallization is a process that forms contact on device and connects individual devices together by thin conductive metal films to form circuits.

- This process produces a thin film of metal layer that will serve as the conductor pattern for the interconnection of the various components inside the chip.

- Another use of Metallization is to produce metallized areas called bonding pads (contacts) around the periphery of the chip to produce metallized areas for the bonding of wire leads from the package to the chip.



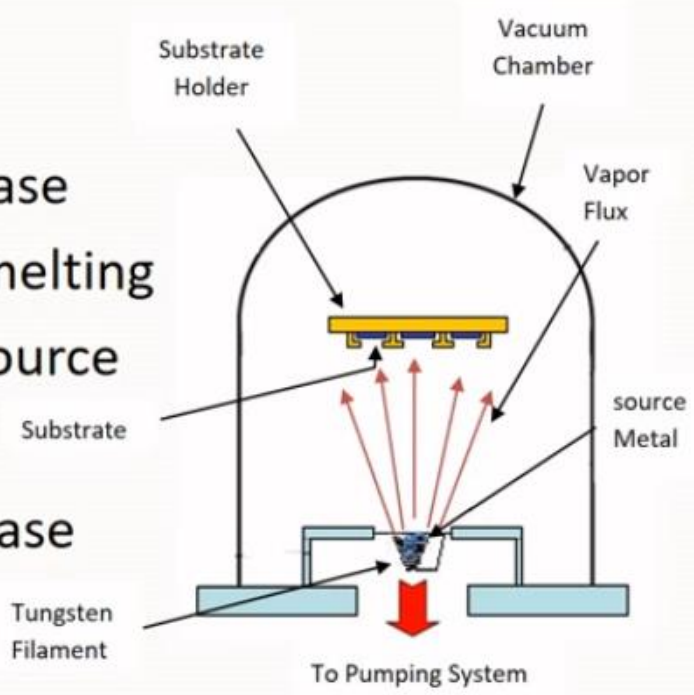
Different methods of Metallization

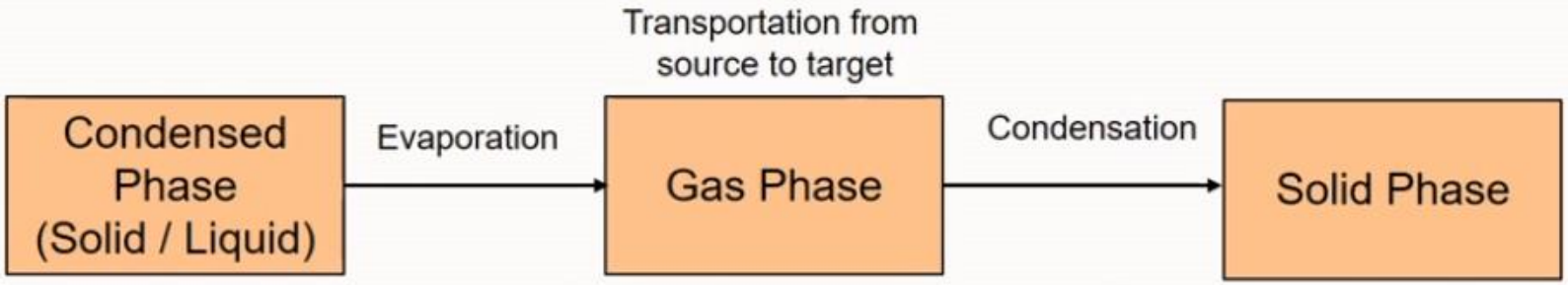
- **Physical Vapour Deposition (PVD):** atoms/molecules (vapor) of the desired material are directly deposited on to the substrate from the vapor phase. PVD is a line of sight deposition technique, so that the substrate must be in front of the source. The material to be evaporated is heated and the atoms are then deposited on the substrate.
  - Thermal Evaporation
  - Electron Beam Evaporation
  - Sputtering

- **Chemical Vapour Deposition (CVD):** use of a chemical reaction from a derivative of desired material which is to be deposited.

Metallization by Thermal Evaporation

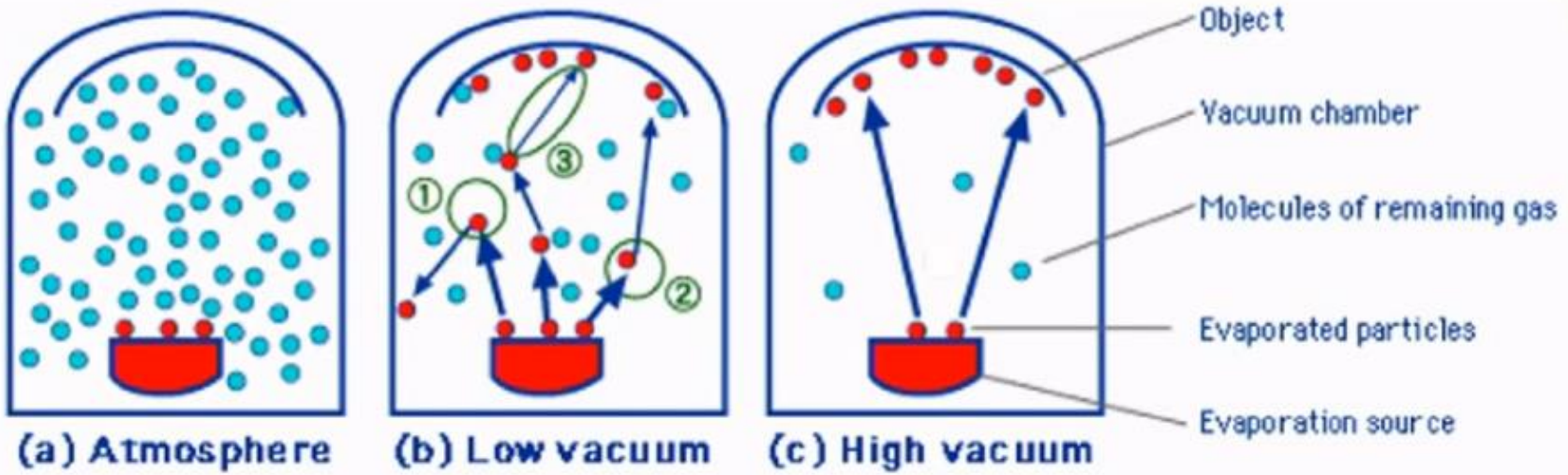
- **Basic Idea:**
  - **Steps involved in the Process:**
    - -- Convert the metal from solid phase to gaseous or vapour phase by melting
    - -- Transport gaseous phase from source to the substrate
    - -- Condensation of the gaseous phase on Substrate





Necessity of high vacuum for Thermal Evaporation

- To reduce the particle density (impurities).
- To remove the air or Gas molecules.
- To reduce the thermal transport to substrate.
- Less current required to achieve desired temperature.
- To increase the mean free path (average distance between two successive collisions)



Blue particles: vapor, oxygen, nitrogen and carbon dioxide in the air
Red particles: materials of the film

- At low vacuum, source particles collide with trace gases leading to Scattering & chemical reaction.
- Only at high vacuum we get high deposition rate and purity.

Metal used for Metallization

- Some metals films that are easily deposited by evaporation:

  Aluminium, Copper, Chromium, Gold, Silver, Titanium, Palladium

❖ Aluminium

Aluminium (Al) is the most commonly used material for the metallization of most IC's, discrete diodes, and transistors. The film thickness is as about 1 micro meters and conductor widths of about 2 to 25 micro meters are commonly used.

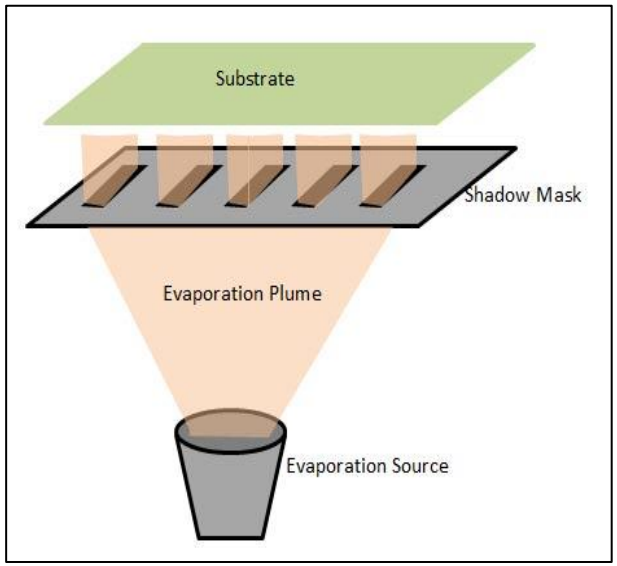
- Advantages:

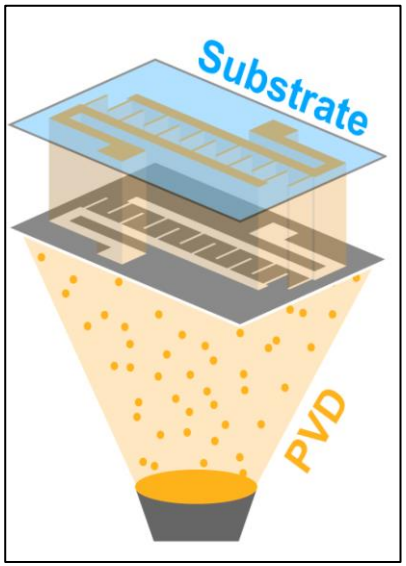
- It has as relatively good conductivity.
- It is easy to deposit by vacuum evaporation (melting point ~ 600˚C).
- It has good adherence to the silicon dioxide surface.
- Aluminium forms low-resistance, non-rectifying (that is, ohmic) contacts.
- It can be applied and patterned with a single deposition and etching process.

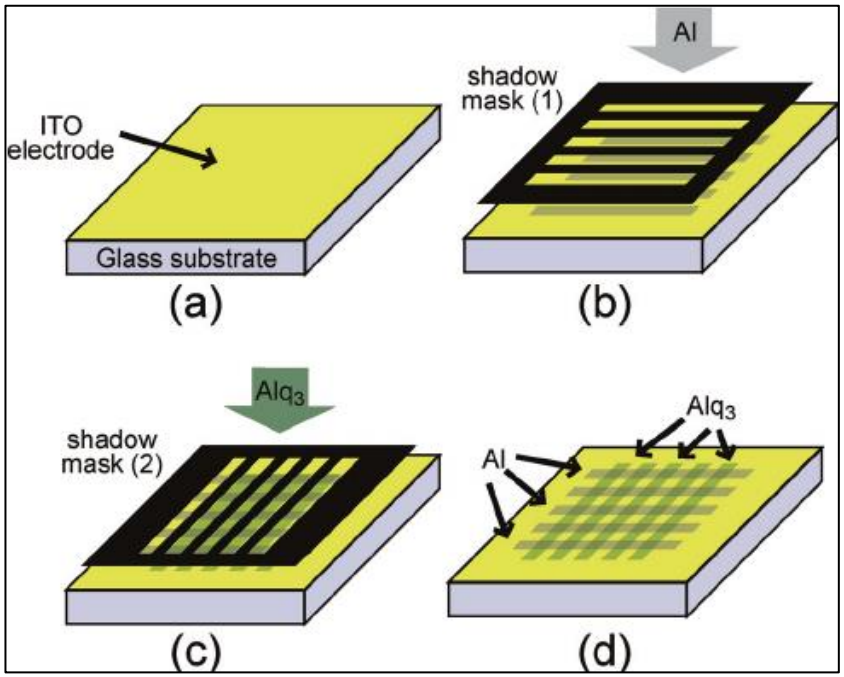
- Limitations:

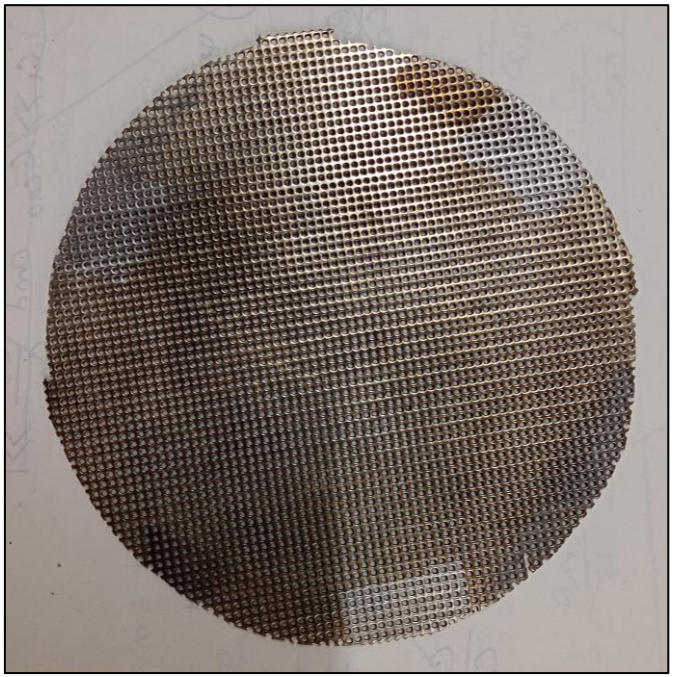
- Cannot withstand high temperature (more than 600˚C) operation.
- Aluminium suffers from electromigration.

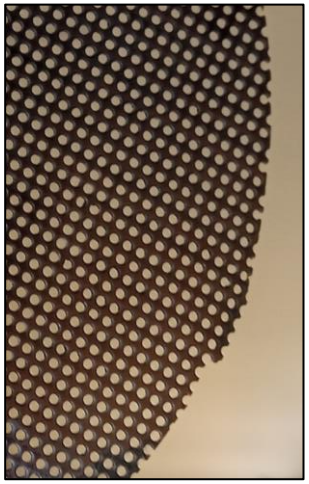
Patterning in Metallization

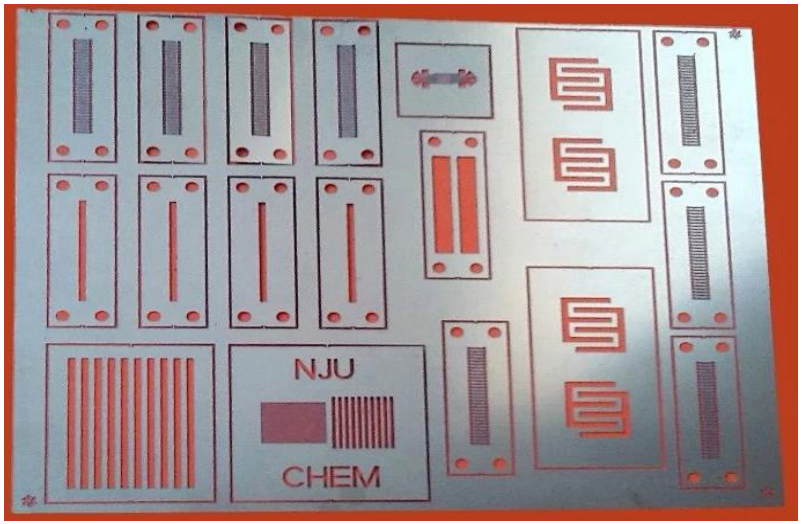




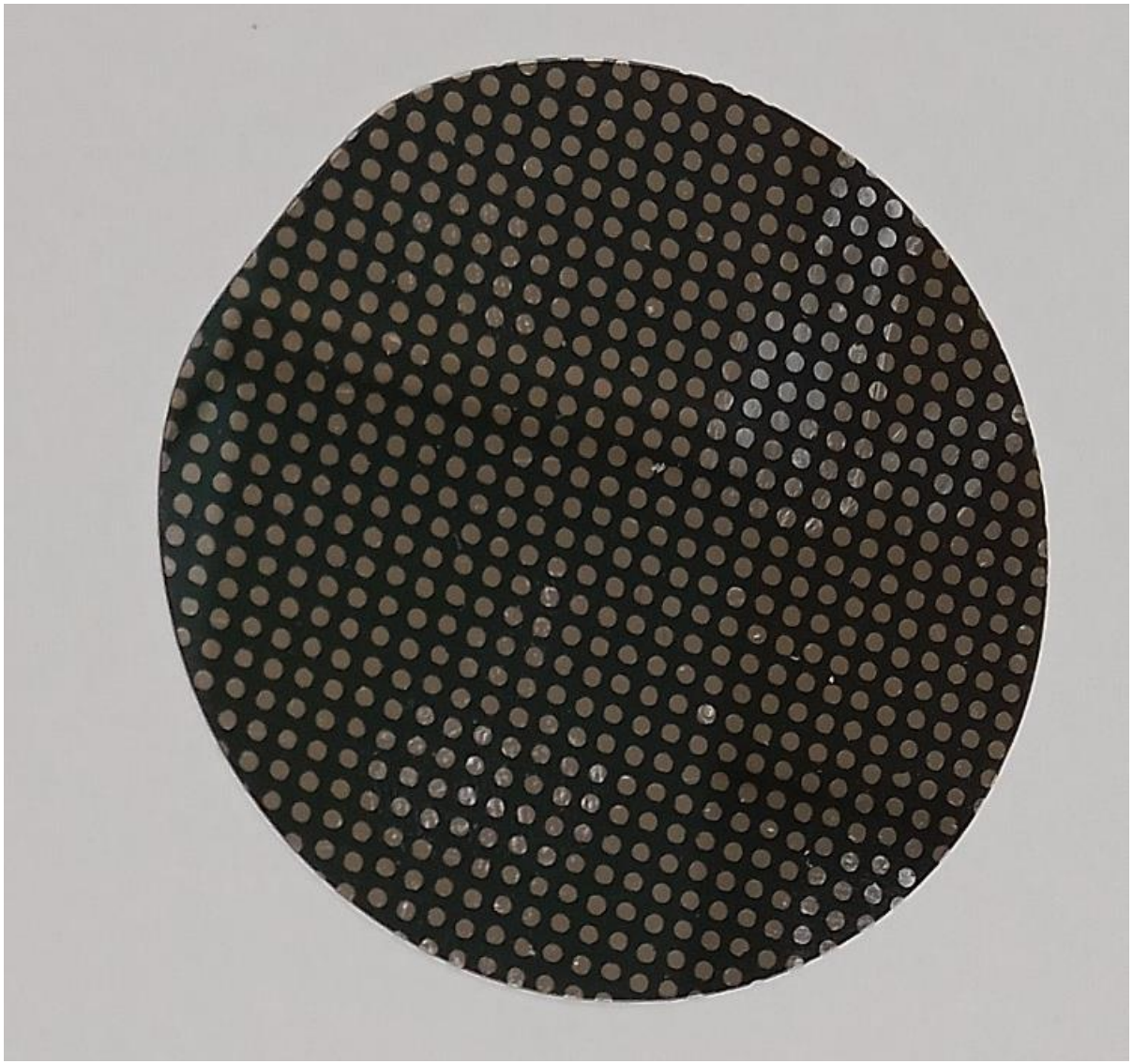






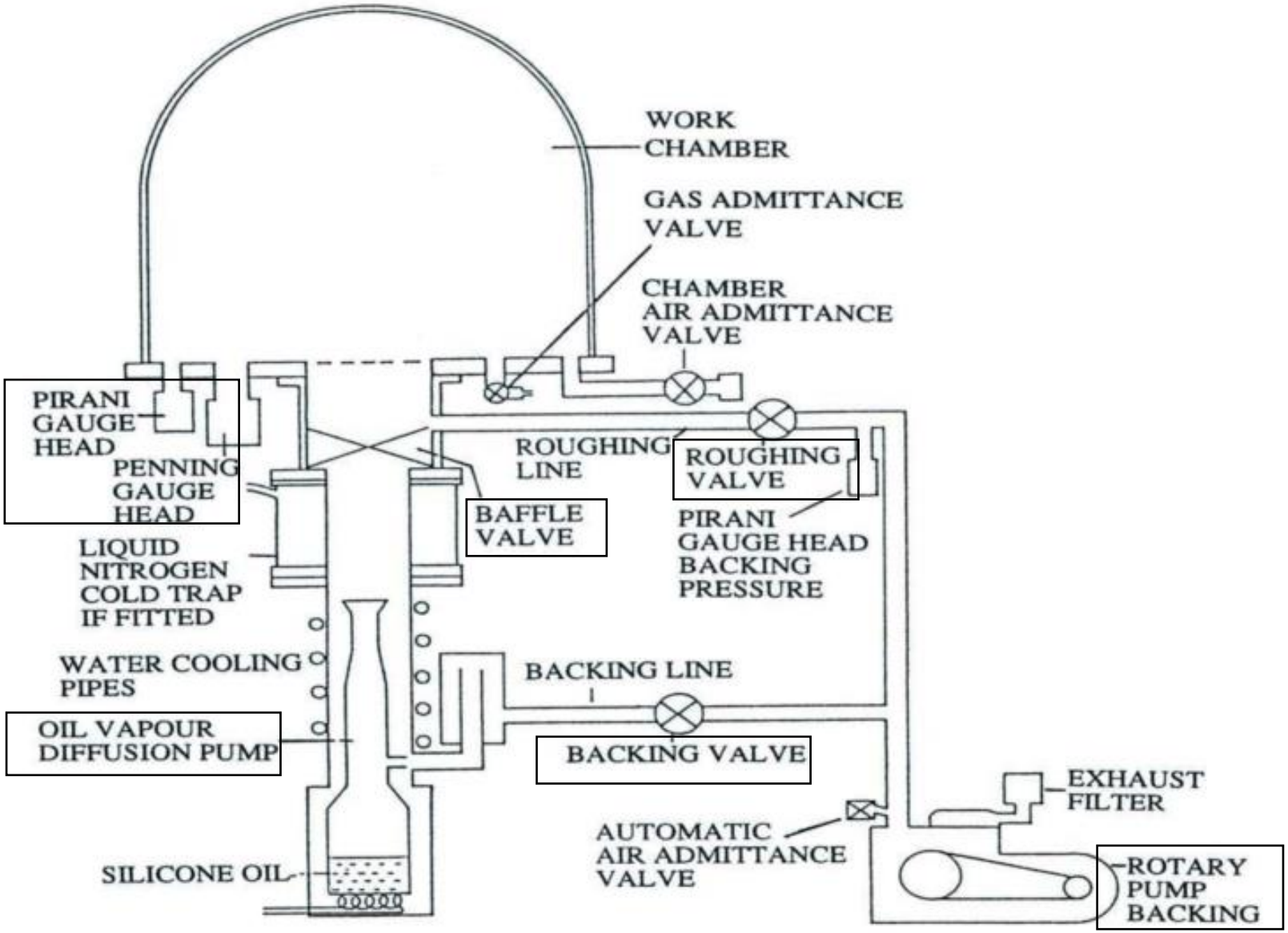


Final Product Obtained



Equipment used for Thermal Evaporation

Schematic Diagram



Experimental Procedure for Metallization of Silicon wafer

1st Step: Switch ON main Power Supply then turn on the Metallization Unit by rotating the knob in ON position. After that turn ON the Start Switch of the Pump.

2nd Step: Open vacuum releasing valve of the vacuum chamber to insert air into the chamber of the Thermal Evaporator.

3rd Step: Open the vacuum chamber of the Thermal evaporator by lifting up the Hoist by rotating the knob into <Hoist up> position. Then place the Tungsten filament at proper position inside the vacuum chamber.

4th Step: Take out the oxidized Silicon wafer and put it in the substrate holder with polished (epitaxial) surface, facing downward of the evaporation source.

Video_1: Opening_Vacuum_Chamber.mp4

5th Step: Take a few pieces of aluminium strips and load them on the tungsten filament (basket) in the vacuum chamber.

Experimental Procedure for Metallization of Silicon wafer

6th Step: Close the vacuum chamber by lifting down the Hoist by rotating the knob into the <Hoist Down> position. Close the vacuum releasing valve of the vacuum chamber.

7th Step: Start evacuating the vacuum chamber by the following methodology:

(a) "Open the roughing valve" by rotating anticlockwise keeping the backing valve closed.

(b) Wait until vacuum reaches up to (10^{-3} mbar) pressure inside the vacuum chamber.

(c) Switch ON the diffusion pump by switching on DIF switch. Wait for 30 minutes for heating up the oil inside the Diffusion Pump.

(d) Measure the pressure inside the chamber with the help of Pirani Gauge (GH2). It may take around 20-30 minutes. Plot the pressure vs time curve.

(e) After reaching desired vacuum level, "Close the roughing valve" by rotating clockwise direction.

(f) "Open the Backing valve" by rotating anticlockwise direction.

(g) After waiting 15 - 20 minutes, turn ON the Baffle Valve (Main Valve) for high vacuum.

(h) Measure the pressure at different times using the Penning gauge. Wait until the high vacuum reached at 10^{-6} mbar pressure.

Video 3: Chamber_Evacuation.mp4

Experimental Procedure for Metallization of Silicon wafer

8th Step: Start deposition by the following methodology:

a) Turn ON the MCB switch <CB2> (8A)

b) Turn ON L.T. (Low Tension) knob into <R.H. & L.T.> position.

c) Set the desired current level by rotating < L.T. > Control variac.

Video 3: Deposition.MOV

9th Step: Measure the thickness of the deposited metal by Thickness Monitor.

10th Step: Stop deposition by the following methodology:

a) Close the <L.T.> Control variac.

b) Turn OFF L.T. (Low Tension) knob into <OFF> position.

c) Turn OFF the MCB switch <CB2> (8A)

11th Step: Turn OFF Diffusion Pump by rotating the knob from <DIF> position to <OFF> position.

12th Step: Close the High Vacuum valve Baffle (Main Valve) and wait for cool down. After cool down properly open the vacuum releasing valve for inserting air inside the chamber.

13th Step: Open the chamber and take out the substrate from the substrate holder of the evaporator very carefully. Video 4: Unloading.MOV

14th Step: Measure the thickness of the deposited metal by surface Profilometer.

Observation & Conclusion

- Observe the deposited film in a microscope and record your observation. Check the uniformity of thickness by taking at different points using Surface Profilometer.
  Video 4:Observation_Profilometer.mp4

- Evaporated material sticks on the surface of the substrate. To check the adhesiveness you may use scotch tape method.
  video 5: Scotch_Tape_metallization.MOV

- Liquid Nitrogen may be used to prevent the oil molecules from the diffusion pump entering into the chamber. Also it helps in achieving a better vacuum.

- Angle of arrival of the flux of the deposited material can affect the step coverage.

- Wafer should be rotate to get uniform deposition.

- Hillok may be formed due to mismatch in thermal expansion co-efficient among deposited metal layer and substrate.

- Electromigration may occur.